

Claims 3-12 and 14-25 were pending. In this submission, claims 1, 3, 5, 7, 9, 12, 13 and 15 have been amended in order to more clearly define protection to which applicant is entitled. Accordingly, claims 3-12 and 14-25 are currently pending in the present application and, for the reasons set forth below, are believed to be in condition for allowance.

SUMMARY OF THE INVENTION

The present invention relates generally to a method for forming a semiconductor device using thin-film transistors (TFTs) mounted on an insulating substrate, such as a semiconductor device utilizable for an active matrix type liquid crystal display. More particularly, the semiconductor device is formed by forming an amorphous silicon film on a substrate, and selectively introducing a metal element which promotes crystallization to a region before or after formation of the amorphous silicon film. The amorphous silicon film is then crystallized by heat, wherein crystal growth is performed in a direction approximately parallel to a surface of the substrate from the region.

PRIOR ART REJECTIONS

The Official Action rejects claims 3-8, 11-12, 14, 16 and 18-25 as anticipated by U.S. Patent No. 5,147,826 to Liu et al. The Official Action asserts that Liu et al. discloses forming amorphous silicon channel pixel TFTs and polysilicon channel driver (peripheral) TFTs on Corning 7059 substrates by forming a thin layer of catalyst material, such as Ni, in contact with the

peripheral regions and subsequently growing 30-40 micron polysilicon regions at a temperature of 550 °C, while other regions where catalyst was not introduced remained amorphous. Thus, the Official Action asserts that the Ni concentration is higher in the peripheral region than in the pixel region. The Official Action further states that it is held, absent evidence to the contrary, that the NiSi front (carrier) moving parallel to the substrate was the leading edge of the recrystallization.

The Applicants respectfully disagree with the Official Action and reconsideration of the rejection is requested. First, Liu et al. does not disclose a direction of crystal growth, and more specifically does not disclose crystal growth in a direction parallel to the surface of the substrate. Furthermore, Liu et al. appears to disclose crystal growth in a direction perpendicular to the surface of the substrate. A thin film of the catalyst material is deposited in a pattern on the amorphous silicon so that only the amorphous silicon deposited beneath the deposited pattern is crystallized during annealing. Through disclosing crystallizing only the area beneath deposited catalyst in Liu et al., this would be inconsistent with a crystal growth parallel to the surface of the substrate since a parallel crystal growth near the edges of the deposited catalyst would extend into an adjacent region not beneath the deposited catalyst. Therefore, Liu et al. would necessary have to grow crystals in a direction perpendicular to the substrate in order to ensure that only the area beneath the deposited catalyst is crystallized, wherein such selective crystallization is the main purpose of Liu et al. Hence, the Applicants believe that claims 3-8, 11-12, 14, 16 and 18-25 are not anticipated by Liu et al.

The Official Action rejects claims 3-8, 11-12 and 14-25 as obvious over Liu et al. in view of either Japanese Patent No. 2-137,326 to Okabayashi et al.

or the article in Applied Physics Letters written by Hayzelden et al., further in view of the article in Phys. Stat. Sol. written by Dvurechenskii et al. The Official Action applies Liu et al. as discussed above, and further asserts that, absent evidence to the contrary, the nickel concentration at the edge of the diffusional (grain growth) region is about  $1 \times 10^{19}/\text{cm}^3$ , since Liu et al. stresses depositing the discontinuous metal catalyst as thinly as possible to minimize the nickel concentration in the device. The Official Action further asserts that Liu et al. teaches that annealing in an oxygen ambient decreases the crystallization temperature. However, the Official Action admits that Liu et al. does not disclose the direction of the crystallization front.

The Official Action asserts that Okabayashi discloses that in a thin nickel doped amorphous silicon, a  $\text{NiSi}_2$  crystallization front moves parallel to the substrate, leaving behind polysilicon. The Official Action asserts that Hayzelden teaches that in a thin nickel doped amorphous silicon, a  $\text{NiSi}_2$  crystallization front moves parallel to the substrate, leaving behind polysilicon with needle like grains and a preferred grain orientation. The Official Action further asserts Hayzelden discloses that crystal growth was parallel to the  $\langle 111 \rangle$  directions. The Official Action asserts that Dvurechenskii et al. disclose that a low dose of nickel, such as  $10^{18} \text{ cm}^{-3}$ , is sufficient to improve a-Si conductivity at 500 °C. Therefore, the Official Actions asserts it would have obvious that the grain growth and the silicon front of Liu et al. move parallel to the substrate as taught by Okabayashi or Hayzelden because they are all examples of nickel silicide mediated recrystallization, which may proceed at low nickel concentrations as taught by Dvurechenskii et al.

The Applicants respectfully disagree with the Official Action and reconsideration of the rejection is requested. First, the Applicants believe that

the cited references do not appear to disclose a crystal growth direction in a semiconductor device, that is, a direction vertical to and parallel to a surface of a substrate. In *In re Dillon*, 16 U.S.P.Q.2d 1897 (1990), the full Court of Appeals for the Federal Circuit held that in making an obviousness rejection, the Patent Office must make a *prima facie* case of obviousness, including both (1) a showing of structural similarity between one or more prior art references and the claimed invention, and (2) some specific motivation in the prior art references for combining the references in the manner asserted. Both Okabayashi and Hayzelden et al., which the Official Action relies upon as teaching a crystallization moving in parallel to the substrate, disclose a nickel disilicide precipitate migrating through an amorphous silicon film. However, as discussed in lines 24-28 on page 7 of the present application, when the concentration of nickel is greater than  $5 \times 10^{19}$  atoms/cm<sup>3</sup>, a nickel silicide is produced which results in losing the characteristics of a semiconductor. In the crystallized state, the lower the concentration of nickel, the more favorably the semiconductor may be used. Hayzelden et al. disclose a nickel concentration of  $2 \times 10^{21}$  in the amorphous silicon film. Therefore, the teachings of Hayzelden et al. and Okabayashi could not be used in the formation of a device having the characteristics of a semiconductor, such as in the present application, and the prior art does not disclose a structural similarity to the present application.

Not only does the prior art fail to disclose a structural similarity to a semiconductor device have crystal growth in a direction parallel to a surface of a substrate, there is no specific motivation in the prior art references for combining the references in the manner asserted. As discussed above, Hayzelden et al. and Okabayashi disclose the use of nickel silicides which,

when formed in an amorphous silicon film, cause the film to lose the characteristics of a semiconductor, which occurs when the nickel concentration is greater than  $5 \times 10^{19}$  atoms/cm<sup>3</sup>. When the concentration of nickel is less than about  $1 \times 10^{15}$  atoms/cm<sup>3</sup>, the effect of nickel as a catalyst for crystallization is decreased. Thus, nickel is used as a catalyst in a semiconductor device in the concentration range of  $1 \times 10^{15}$  atoms/cm<sup>3</sup> -  $5 \times 10^{19}$  atoms/cm<sup>3</sup>. Therefore, one skilled in the art would not be motivated by the teachings of Hayzelden et al. and Okabayashi to use their disclosed methods of crystallization in a semiconductor device. Furthermore, since Liu et al. would necessary have to grow crystals in a direction perpendicular to a substrate in order to ensure that only the area beneath the deposited catalyst is crystallized, wherein such selective crystallization is the main purpose of Liu et al., one skilled in the art would be motivated against using the parallel growth teachings of Hayzelden et al. and Okabayashi in the crystallization method of Liu et al. Accordingly, Applicant believe that claims 3-8, 11 and 14-25 are not obvious over the combination of cited prior art and reconsideration is respectfully requested.

The Official Action rejects claims 9 and 10 as being obvious over Liu et al. in view of Okabayashi et al. or Hayzelden et al. together or further in view of Dvurechenskii et al. as applied to claims 3-8, 11-12 and 14-25 above, and further in view of either U.S. Patent No. 5,278,093 to Yonehara or U.S. Patent No. 4,354,191 to Wada et al. or U.S. Patent No. 4,309,224 to Shibata or Japanese Patent No. 55-162,224 to Shibata. The Official Action admits that Liu et al. do not teach irradiating the polysilicon after thermal recrystallization. The Official Action asserts that Yonehara, Wada et al., Shibata and Shibata disclose that flash lamp and laser irradiation of

recrystallized polysilicon improves its properties, such as mobility. Therefore, the Official Action asserts it would have been obvious to irradiate the TFTs of Liu et al. after recrystallization in order to improve their mobility. Because claims 9 and 10 ultimately depend upon independent claims 3 and 4 and Liu et al. fails to disclose crystal growth in a direction parallel to the surface of the substrate, one skilled in the art would not be motivated to combine the above references to yield the present invention. Reconsideration is requested.

FORMALITIES

The Official Action further rejects claims 3 and 4 under 35 U.S.C. § 112, second paragraph, as being indefinite, wherein the Official Action lists numerous informalities and possible corrections to the informalities. The Applicants have amended claims 3 and 4 to include the suggested changes in the Official Action. Reconsideration is requested in view of the above amendments.

Furthermore, the Official Action asserts it is unclear what is meant by the term "carrier" in claims 4 and 21-22.

In claims 4, 21 and 22, "a carrier moving direction" represents a direction which a carrier moves in a TFT, and relates to a mobility of the TFT. This direction corresponds to a direction connecting a source with a drain in the TFT.

The Official Action rejects claims 14-25 under 35 U.S.C. § 112, second paragraph, as being indefinite, wherein the Official Action lists numerous informalities and possible corrections to the informalities. The Applicants have amended claims 14-25 to increase their clarity and to include the

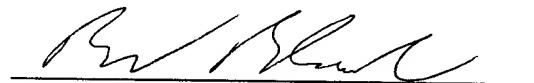
suggested changes in the Official Action. Reconsideration is requested in view of the above amendments.

In paragraph 9 of the Official Action, the Examiner inquires by which mechanism low temperature crystallization proceeds. In the present invention, a small amount of nickel is added to crystallize an amorphous silicon film by heating or the like. When a concentration of nickel is less than about  $1 \times 10^{15}$  atoms/cm<sup>3</sup>, the effect of nickel as a catalyst for crystallization is decreased. Also, when the concentration of nickel is greater than  $5 \times 10^{19}$  atoms/cm<sup>3</sup>, NiSi is locally formed to lose the characteristics of a semiconductor. Thus, in this concentration range, nickel is used as a catalyst. The Official Action asserts that Kuznetsov et al. discloses that for nickel concentrations below  $10^{19}$  cm<sup>-3</sup> no catalyst mediated recrystallization occurs. However, the Applicants respectfully disagree with this interpretation of the teachings in Kuznetsov et al. Although Kuznetsov et al. disclose that at low concentrations ( $< 10^{19}$  cm<sup>-3</sup>) Ni does not segregate in the amorphous layer, it appears that this does not lead to no catalyst mediated crystallization occurring.

CONCLUSION

In each case, the pending rejections should be reconsidered in view of the amendments and remarks herein. Applicants believe that this case is in good condition for allowance, and a Notice of Allowance is earnestly solicited. If a telephone or further personal conference would be helpful, the Examiner is invited to call the undersigned, who will cooperate in any appropriate manner to advance prosecution.

Respectfully submitted,



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Bradley D. Blanche  
Reg. No. 38,387

Sixbey, Friedman, Leedom & Ferguson, P.C.  
2010 Corporate Ridge, Suite 600  
McLean, Virginia 22102  
(703) 790-9110  
(703) 883-0370 - FAX